FARM FACTS

Managing Manure as a Fertilizer

Published by Saskatchewan Agriculture and Food

When used properly, animal manure can be a valuable source of plant nutrients and organic matter to improve crop production and soil quality. Animal manure contains most of the nutrients that crops require, including nitrogen, phosphorus, potassium, sulphur, calcium, magnesium, copper, manganese, zinc, boron and iron (Table 1, also see FarmFacts: *Nutrient Values of Manure*). Animal manures can be solid, semi-solid or liquid:

Solid - <80% moisture content
Semi-solid - 80%-90% moisture content
Liquid - >90% moisture content

Solid and semi-solid manures have a higher organic content than liquid.

When using manure as a fertilizer, it is important to understand that only a portion of the manure nutrients are immediately available.

A major difference between animal manure and commercial inorganic fertilizers is that some of the nutrients in manure are in the organic form and must go through a decomposition process (mineralization) in order to be converted to inorganic forms available for plant uptake. This makes animal manure a more slowly available source of plant nutrients than commercial inorganic fertilizer N. However, it is the organic fraction of manure that also plays an important role in increasing soil organic matter content and tilth.

Table 1. Typical nutrient contents in liquid swine effluent and fresh cattle pen manure samples in Saskatchewan. (Research by J. Schoenau, 1998-00)

	Liquid Swine Manure *(feeder hogs)* Pounds per thousand gallons	***Fresh Cattle Penning Manure*** *(with straw bedding)* % on dry weight basis
Nitrogen (N)	15 – 50	0.5 - 1.5
Phosphorus (P)	1 – 20	0.5 – 1.5
Potassium (K)	8 – 20	0.8 – 1.5
Sulphur (S)	0.1 – 3	0.08 – 0.15
Copper (Cu)	0.05 – 0.5	0.01
Manganese (Mn)	0.05 – 0.5	0.02
Zinc (Zn)	0.05 – 1.0	0.02
Boron (B)	0.01	0.005

Note: *multiply P by 2.3 to convert to P_2O_5; multiply K by 1.2 to convert to K_2O.*

Despite the value of manure as a fertilizer and soil amendment, there are challenges in effectively using manures as fertilizers. Some of these challenges are:

1. Variability in nutrient content and form, which necessitates manure sampling and analysis to determine appropriate rates of application to meet crop nutrient requirements.

2. Manure is not an "off-the-shelf" fertilizer and may not match the crop's relative requirements. Examples of this would be manures that contain more phosphorus relative to nitrogen than what the crop can use, or an inadequate amount of sulphur relative to nitrogen.

3. Low nutrient content per unit weight or volume, which limits the distance which manures can be transported economically.

As with any fertilizer, over-application of manures (e.g. repeated application at rates which greatly exceed the crop nutrient removal) and improper application increases the risk of manure nutrient losses to the environment and deterioration of environmental quality. Concerns include:

1. Transport of nutrients to ground water and surface water bodies through leaching and overland flow.

2. Escape into the atmosphere of gases such as ammonia and nitrous oxide derived from manure nutrients.

3. Accumulation of manure salts under conditions of poor drainage, leading to development of saline and sodic soils.

The risk of manure nutrient accumulation and loss can be minimized and the maximum agronomic benefit realized from these nutrients through the use of sound manure nutrient management practices. Some guidelines are covered in the following section.

A. *Know the Forms and Amounts of Each Nutrient in the Manure*

While tables of typical manure nutrient contents can be useful in making general interpretations about nutrient form, content and behavior, a laboratory analysis of a representative sample of the manure will give the best indication of the nutrient value of the manure and will be useful in determining the appropriate rate of application for the crop to be grown. Because of the high variability in nutrient content even within a single storage unit, several sub-samples should be taken and combined for analysis to arrive at the average nutrient level. However, there is an urgent need to develop accurate nutrient sensing systems for on-the-go measurement.

Many commercial laboratories on the prairies offer manure analysis and crop recommendation packages based on an analysis of the manure and a soil sample. Note that residual organic fraction nutrients are not picked up in regular soil tests so one must be careful about loading. Keep good records for each field. Budgeting of nutrients added to and removed from the field is desirable.

Nitrogen:
Considerable variability can exist in manure nutrient content and form, depending on type of livestock operation, handling and storage procedures, feeds and feed supplements used, etc. For example, in Saskatchewan, a typical range in total nitrogen (N) content of swine effluent from earthen manure storage units is from 15 to 50 pounds of total N per thousand gallons. Of this total N, from 30% to 90% of it is comprised of ammonium, which is a form that plants can use directly. The rest of the N is contained in organic forms, which must be decomposed (mineralized) to inorganic forms to be rendered plant available. It is estimated that about 20% to 30% of the organic N in liquid effluents is mineralized to plant available inorganic forms in the year of application. Most manure contains low amounts of nitrates. The nitrates found in manured soils are derived from conversion of ammonium to nitrate by microorganisms in the soil (nitrification).
Solid cattle penning manure, which contains both fecal matter and straw bedding, typically has only 10% to 20% of the N present as ammonium, with most of the N present in the organic form.

Owing to differences in the forms of N present in manure, different patterns in availability are observed over time. Manure with a higher content of immediately available ammonium will have a larger effect on increasing the N availability in the year of application. A good example of this is liquid swine effluent with about 50% of the N present as ammonium. Field studies in Saskatchewan have revealed that the availability of N from a manure source such as this in the year of application is about 60% to 70% of that observed for urea at equivalent rates of added N.

On the other hand, N availability from cattle manure is more difficult to predict because of variability in the rate of release of available N from decomposition of the organic N, which comprises the majority of N in solid manures. The bedding material used, the amount of fecal material relative to bedding, and age and degree of decomposition of the manure affects the rate of release of available N in the decomposition process. Fresh straw or wood chips in the manure can temporarily tie up (immobilize) available N when it decomposes. For this reason, availability of N in penning manure that contains a lot of straw can be low in the year of application (e.g. 10% of that for urea).

Composting of manure and decomposition of manure in the soil will gradually increase the N content of the manure relative to the carbon content over time and allow for the N to be eventually released. For this reason, solid manures with straw bedding are usually more slowly available sources that may take several years to release their N.

Phosphorus:
The total phosphorus (P) content is also directly related to the solids content of the manure and tends to be more variable than the N content,

exhibiting a wide range of values in recent testing in Saskatchewan. The range of total P content in liquid swine effluent samples was found to be from 1 to 20 lbs of total P (multiply by 2.3 to express as P_2O_5) per thousand gallons. From 10% to 50% of the total P in effluent samples was present as readily soluble inorganic phosphate. The availability of phosphorus in manure in the year of application is estimated to be about 50% of that observed for inorganic fertilizer P sources and decreases as the content of readily soluble phosphate in the manure decreases.

Of the solid manures, poultry manure is highest in P. As with N, mineralization of organic P to plant available phosphate takes place and also contributes to the supply of plant available P. Manure P tends to be readily fixed in Saskatchewan soils by sorption and precipitation reactions. However, over several years soil test phosphorus levels will increase in soils receiving repeated applications of manure, especially in sandy soils. Soil P levels should be monitored in manured soils as applying manure at rates to meet N requirements may result in accumulation of residual manure P over time.

Potassium:
Manures are effective sources of potassium (K) for plant growth, as the K in manure is readily available. In liquid swine effluent samples there is about the same amount of K as ammonium (NH_4) (8 to 20 pounds of K per thousand gallons, multiply by 1.2 to express as K_2O).

Sulphur:
Some animal manures like liquid swine effluent tend to be low in sulphur (S) relative to N , such that high S demanding crops like canola may respond to supplemental S fertilization.

Micronutrients:
Manures also contain micronutrients including copper, manganese, zinc and boron. There is less information on the forms and availability of micronutrients in manure than macronutrients, as micronutrient chemistry in manures and soils is complex. Micronutrient metals may be present in manures as soluble free and complexed cations, as well as adsorbed and precipitated in the solid phase. Micronutrient levels should be monitored in manured soils and a tissue test can be a good diagnostic tool to determine if a deficiency or excess of a macro and/or micronutrient is becoming a problem.

B. *Match the Application Rate with Crop Demand*

Crop response to manure additions observed in recent field trials in western Canada have been used in the development of recommendation tools for rate of manure to apply to meet the crop's nutrient requirements. There are computer programs available that can assist with matching application rates to crop demand as well as record keeping. The recommended rates vary according to manure nutrient content and predicted availability (manure test), the nutrient that is already available in the soil (soil test), and the anticipated crop nutrient requirement which depends on type of crop grown and environmental conditions (target yield). Crops with high nutrient demand and removal potential such as forage grasses and high yield potential cereals and oilseeds have shown good yield response to the nutrients provided by manure application (Table 2). Protein content in cereals can also be significantly increased by the application of manure because of mineralization of N later in the growing season.

Over-application has been shown to have a harmful effect on crop growth and yield in trials, with high rates of liquid swine effluent (e.g. greater than 10,000 gallons per acre) sometimes causing germination and emergence problems in annual crops, lodging, and large amounts of residual inorganic N in the soil after harvest. This residual inorganic N can carry over and provide a nutritional benefit in the second year but

Table 2. Yield increase of an oilseed (canola), a cereal (barley) and a forage grass (crested wheat grass) from injected swine manure effluent in east-central Saskatchewan.

Rate	**Canola Yield**	**Barley Yield**	**Crested Wheat Grass**
Gallons / acre	*Bushels / acre*		*Tons / acre*
0	10	38	0.43
3300 (75 lbs N / acre)	23	75	1.10
6600 (150 lbs N / acre)	31	80	2.02
13,200 (300 lbs N / acre)	29	74	1.98
Urea check (100 lbs N/ acre)	26	76	-

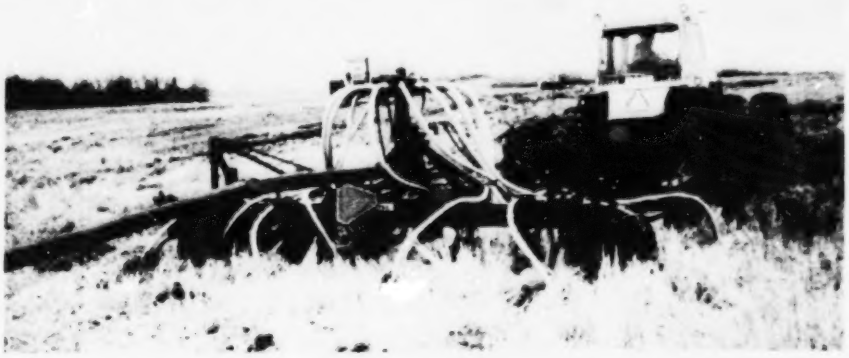
is also susceptible to loss before the next growing season. Repeated applications of swine effluent at rates (e.g. 300 pounds N per acre per year) that were greatly in excess of crop requirements were found to result in significant amounts of nitrate N below the top 24 inches of soil after three years. In drier areas, high rates of manure may produce a large amount of vegetative growth, especially in cereals, but with subsequent poor grain fill and yield if the weather turns dry later in the season ("haying off"). In forage grasses, high rates of N applied as manure may elevate the nitrate content of the forage, especially if forage growth is limited by some factor such as drought or frost. Feed testing of forages grown on manured soils is recommended to determine nitrate levels.

C. *Use Application Methods that Maximize Crop Nutrient Recovery*

Technology for application of liquid manure has progressed rapidly in the past few years. Effluents can be delivered to a toolbar using a manifold distribution system coupled to a drag hose or tank to supply the manure. Systems commonly employed to inject liquid manures include sweeps and low disturbance systems using knives or coulters (Figure 1). The low disturbance openers are suitable for liquid manure application in both annual crops and forages.

Injection of manure reduces odor and has been shown to increase crop use of N compared to surface placement. Row spacing of manure injectors should be less than 18 inches to get good distribution of nutrients for uniform access by plants. Similar to commercial inorganic fertilizer N, applications of manure later in the fall when the soil has cooled will reduce conversion of the ammonium N to nitrate and help prevent losses by leaching and denitrification.

Figure 1. A low disturbance injection system for applying liquid effluent in annual crop and forage lands.



In the case of solid manure, suitable technology has not yet been developed for placement of the solid manure below the soil surface with minimal disturbance. Broadcasting of solid manure is therefore usually followed by incorporation with a tillage implement to reduce volatilization losses of ammonia. For solid cattle manure with significant amounts of straw, immediate versus delayed (24 hour) incorporation did not have a large influence on nitrogen recovery. However, volatilization losses associated with delayed incorporation will be higher when the manure contains a higher proportion of fecal material and nitrogen in the ammonium form.

Animal manure can be an effective source of nutrients for crop growth and should be viewed as a resource rather than as a waste product. As with commercial inorganic fertilizers, when managed properly they can provide economic return for the user and do not adversely impact the environment. Both liquid and solid manures provide nutrients in fairly low concentrations by volume when compared to a commercial fertilizer. As a result, current limitations to more widespread use are mainly in transportation costs, as break-even hauling distances for unprocessed manure are typically only a few kilometers from the site of the manure production. Composting and other processing techniques that help reduce the volume of manure will increase the economic hauling distance.

Prepared by: J.J. Schoenau, K. Bolton, K. Panchuk. Reviewed by the Saskatchewan Advisory Subcouncil on Soil Fertility and the Saskatchewan Manure Management Working Group.

The funding for the research and printing of this FarmFacts has been provided by the Canada-Saskatchewan Agri-Food Innovation Fund.

Saskatchewan Agriculture and Food

Printed November 2000
5M ISSN 0840-9447 SUSMMF1100